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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: PORTABLE APPARATUS FOR SELF-CHECKING FEMALE BREASTS OR TESTICULAR TISSUES

(57) Abstract: The invention described here relates to an inexpensive domestic instrument primarily for examining female breasts at repeated intervals. It is not a diagnostic device but is designed to indicate the need, or otherwise, for the woman to go for medical advice, clinical breast examination and, if necessary, for investigation in a clinical setting. The invention packs into a small suitcase. It indicates any changes in the optical properties of breast tissues and whether, associated with the geometrical focus of that change, there are associated vascular changes which could be indicative of malignancy. The device permits visual examination of the breast for areas of increased optical absorption and emits audio frequency sounds caused by blood flow if the disease/tumour is vascularised. An audio / video tape supplied with the device demonstrates to the woman sounds which indirectly emanate from breast tissues. Ideally the device is used by the subject's husband or partner on a regular basis [monthly intervals are ideal] so that both parties recognise normal images and sounds. Observation of changes in either optical or vascular properties or both indicate the need for a medical opinion.

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PORTABLE APPARATUS FOR SELF-CHECKING FEMALE BREASTS OR TESTICULAR TISSUES

The device comprises a torch emitting light in the red and near infra-red region of the spectrum [about 530-650 nm] along a curved light guide. The cylindrical guide is typically formed of solid perspex rod [about 30 mm diameter] and has an outer wall covered in reflective foil held in place by heat shrink tape. A means for varying the light output, typically by varying the voltage applied to the filament of a quartz halogen bulb, is included. A suitable light source is a 75 Watt bulb with reflector. Along the centre of the light guide is a cylindrical hole typically 7 mm diameter. At the exit pupil is a circular recess of depth about 1mm and typically of diameter 10 mm. Into the recess are fixed two semi-circular piezoelectric transducer elements [diameter typically 8 mm]. A screened conductive wire is affixed to the front and back surface of each element. [There are 4 wires altogether]. The front face of the transducers is covered by a thin layer of epoxy resin or similar material. The wires are fed down the central hole in the light guide. One semi circular piezoelectric element transmits continuous wave ultrasound at a frequency of about 5 MHz and the other receives Doppler frequency shifted scattered sound waves arising from motion of red blood cells. This effect occurs provided that the volume being examined is vascularised. If there is no tumour associated angiogenesis no characteristic signals will be received. The difference frequency between transmitted and received sound depends on blood flow velocity. The fact that in the case of a cancer there is a chaotic mass of vessels with diffferent diameters means that there is in reality a spectrum of Doppler shift frequencies. The difference frequency lies in the audio frequency range and for typical blood flow around tumours this range is 50Hz to 3 KHz. By demodulating the received radiofrequency signal and amplifying it, an audio frequency output via a loudspeaker located in the instrument can be made to alert the woman and her partner to the onset of abnormal vascular sounds. It is feasible to include in the instrument a means for displaying the frequency spectrum of the Doppler sounds. Other operating frequencies up to about 12 MHz can be used for the transmitted signal but adequate penetration of

ultrasound into human tissues requires a degree of compromise and we have found 5 or 8 MHz to be satisfactory.

The device can differentiate between a single normal vessel and a collection of vessels which arise when a cancer is present. When the probe is moved through a small arc angiogenesis which is chaotic gives rise to a signal whose amplitude is angle independent. On the other hand a normal vessel will give a signal strongly dependent on angle subtanded by the probe.

An alternative arrangement to the two semicircular piezo elements is to utilise four quarter sized elements [i.e. a circular element sawn into four equal segments]. The reason for this choice is that with two semi-circles the received ultrasound signal depends on angle of rotation [as well as angle subtended in the direction of a vessel]. This rotational effect arises because of ultrasound beam asymetry. With four segments, 2 transmitting and 2 receiving and with diagonally opposite elements connected together, the signal dependence on angle of rotation is greatly reduced.

Although a circular light guide proves suitable for examining most women with medium and large breasts some women with small breast require a curved light guide but tapered at the exit pupil to a rectangular shape. This modified version of the light guide prevents the observer receiving light directly from the torch which has not not passed through breast tissues. It also has the effect of minimising back scattered light.

The examination is best conducted with the woman seated on a bed or rotating chair with the clothes on her upper body removed. Her partner applies the torch to the underside of first her left breast then the right. He and she view the superior breast surface with light transmitted through the tissues. In a normal healthy woman both breasts will show uniform brightness except for occasional dark lines arising from shadowing by large superficial blood vessels. If there are any dark shadows seen on the superficial aspect of either breast the ultrasound transducers are excited and Doppler shift sounds elicited from the tissue portion immediately under the area of increased optical density. The torch is moved by small angles around this spot and if the periodic

sound persists independent of angle of the probe the examination is regarded as positive. The indication is for the woman to go for medical examination and if advised investigation in a diagnostic setting. If the outcome of the examination with the breast-checker is normal a repeat examination is performed the following month.

Although this instrument is designed for use by women in the home there are some countries where sophisticated equipment such as X-ray Mammography, MRI, colour flow Doppler Ultrasound imaging and CT scanners, are not widely available and in such circumstances the device described here can aid the physician in reaching a diagnostic conclusion at least as far as proceeding to biopsy.

The transcutaneous measurement of blood flow velocity by ultrasound Doppler frequency shift is a well established technique, Wells et al [1977]. US Patent 5,007,428 Watmough teaches of the need to use a combined optical and ultrasound Doppler technique to distinguish between breast or testicular cancers and haematoma or bruising. In that case the optical and Doppler tests are separate but utilise the same computer to capture and store the images and to process Doppler ultrasound data. The patent does not envisage combining the ultrasound transducers in the exit pupil of the light guide. The pending application PCT / GB01/ 00549 entitled Angiotracker is an instrument based around a computer and did not envisage the ultrasound transducers situated centrally in the light guide. The Angiotracker was not designed to alert the subject/user of the need to go for a check up. Rather it was designed to monitor the effect of treatment of breast cancers by anti-angiogenic drugs. The breast checker described here would appear to be unsuitable for monitoring the effects of treatment by anti-angiogenic drugs since the Doppler blood flow study is confined to study of a small portion of the advancing front of the tumour.

Key to figures:

Figure 1. A female breast observed by transillumination, showing areolar and nipple. Superficial blood vessels are also indicated.

Figure 2. Torch 30, applied to inferior aspect of female breast 32 and area of suspicion 31.

Figure 3. Breast image as in figure 1 but with cancer seen as large dark area centrally placed in the image. A blood vessel at 2 o'clock is clearly delineated.

Figure 4. Torch for transilluminating breast tissues showing fan 8, bulb 7, reflector 3, cable access 1, outer wall 2, heat absorbing filter 4, on / off switch 8, light guide 5, central conduit 9. The piezoelectric transducer for transmitting and receiving ultrasound are not shown in this view but see figure 5.

Figure 5. Piezoelectric elements 13 and 14, conduit 11, epoxy layer 10, perspex body of light guide 12.

Figure 6. Shows semi-circular piezoelectric elements 15 and 16 in recess in light guide.

Figure 7. Arrangement of 4 segments, 17, 18, 19 and 20 to minimise effect of angle of rotation of probe on amplitude of Doppler ultrasound generated audio signals.

Figure 8. Instrument for breast checking in a suitcase. Torch 23, alternative end-pieces 24 and 29, light intensity controller 22, loudspeaker for providing audio signals from blood flow study, Display showing frequency components of Doppler shift sounds, on / off and filter switches for controlling unwanted noise on audio output.

Figure 9. Light guide with tapered end piece to suit women with small breasts.

Figure 10a, 10 b, 10 c. Typical circuitry used for ultrasound transmitter and receiver, demodulator and audio frequency amplifier are appended.

Figure 11. Engineering drawings of light source not to scale.

The invention is described by way of example.

Figure 1 shows an image obtained by transillumination recorded on photographic film and shows what an observer [woman or partner] will see when the subject is in a darkened room with the arrangement shown in figure 2. The areolar and nipple are clearly delineated in figure 1 as dark colours but there are no other dark areas apart from those arising from a few superficial blood vessels. A change in optical properties of tissues caused by occurence of a cancer produces a dark brown or black area on the superior aspect of the breast.

Figure 3 shows such a large dark area caused by a cancer, in this instance recorded by an infra-red sensitive video camera. Figure 4 is a line drawing of the light torch omitting details of the ultrasound transducers in the exit pupil but showing the central hole in the light guide which carries the four wires along which sinsoidally varying electrical signals to and from the piezoelectric elements are fed and received.

The large dark area centrally situated, seen in Figure 3, is due to light absorption by angiogenesis surrounding a cancer deep in breast tissue. The nipple [small round dark area] and the superficial blood vessel [black line] on the right of the picture are typical features of optically produced images. Figure 5 shows a detail drawing, not to scale, of the end of the light guide with two piezoelectric elements recessed into a central well and covered by a layer of sealant, typically epoxy resin. Alternatively the piezoelectric elements may also be glued to a thin disc and then it is fixed to the end of the light guide.

Figure 6 shows a view looking down on the exit pupil showing the semi-circular elements side by side in the recess.

An improved arrangement shown in figure 7 shows four quartered segments. These are wired together so that diagonally opposite pairs transmit and receive. This makes the amplitude of the received Doppler signals almost independent of the angle of rotation of the probe.

Figure 8 shows the arrangement of the torch and power supplies in the carry case. A loudspeaker to indicate vascular changes in breast tissues is not shown. It can conveniently be set into the side or lid of the instrument case. The transmitter and receiver are situated behind the control panel and are indicated by circuit diagrams appended as figure 10. An alternative arrangement is for transmit and receiver electronics to be placed within the torch housing. This choice has the effect of reducing unwanted noise pick up.

Figure 9 is a schematic representation of an interchangeable tapered light guide included for use by women with smaller sized breasts.

Figure 10 represent typical circuits for detecting blood flow in and around areas of tissue suspected of harbouring breast disease. They produce corresponding indicative audio signals which are reproduced by an audiofrequency amplifier feeding a loudspeaker or headphones. An output to a means for storing and analysing this acoustic data can be included.

Typical electronic circuitry for driving ultrasound Doppler system is shown in figure 10.

CLAIMS:

1. A portable apparatus for examining the breasts of well women, or testicles of men, comprising a light source for illuminating the tissues and piezoelectric sensors incorporated centrally in a light guide to provide means for applying ultrasound to regions of tissue suspected of harbouring breast or testicular disease. Incorporated in the optical applicator, is means for transmitting ultrasound and receiving scattereded ultrasound from red blood cells in the tissues. The Doppler frequency shift signals which are detected by demodulating received signals are representative of the velocity of blood flow in that region of tissue.

2. An apparatus according to claim 1 wherein means for applying ultrasound and means for receiving reflected ultrasonic signals comprises an ultrasonic Doppler bloodflow detector whose piezoelectric transmitting and receiving elements are incorporated in the housing of the light guide and the conductors carrying the signal are placed, at least in part, along a central bore in the guide.

3. An apparatus according to claim 1 or claim 2 further comprising a light source where electronics for transmitting and receiving ultrasound are housed in the torch.

4. An apparatus according to claims 1, 2 and 3 where the piezoelecric elements and electronics operate at frequencies from 2 MHz to 15 MHz.

5. An apparatus according to claims 1,2, 3, and 4 where the transducers are in 4 quartered segments, diagonally opposite elements being joined together for transmit and receive modes.

6. An apparatus according to claims 1, 2, 3, 4 and 5 where the light source, piezoelectric elements, Doppler electronic circuitry, audio frequency amplifier and loudspeaker are contained in a small suitcase.

7. Apparatus according to claims 1 - 6 but with a red and a green LED situated in the suitcase, together with a switch and microprocessor so that based on the Doppler shift frequency spectrum the subject can be directed towards taking medical advice, or not, by virtue of whether green or red lights are illuminated at the conclusion of the examination.

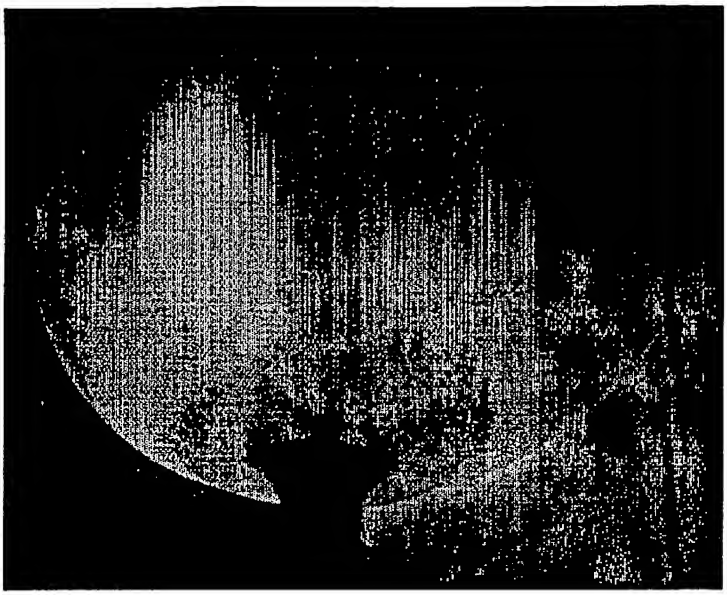


Figure 1.

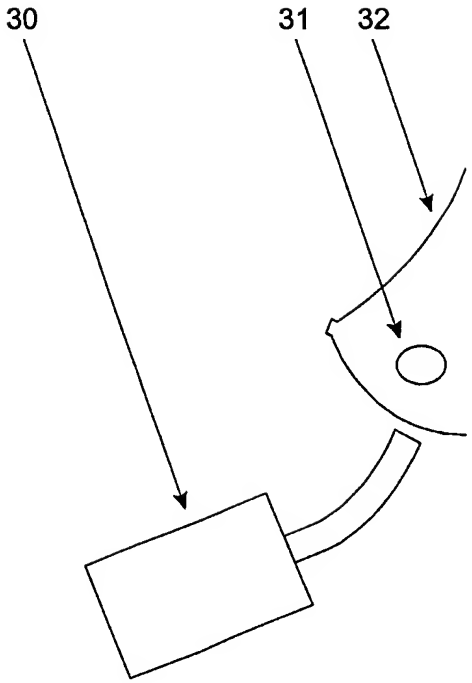


Figure 2

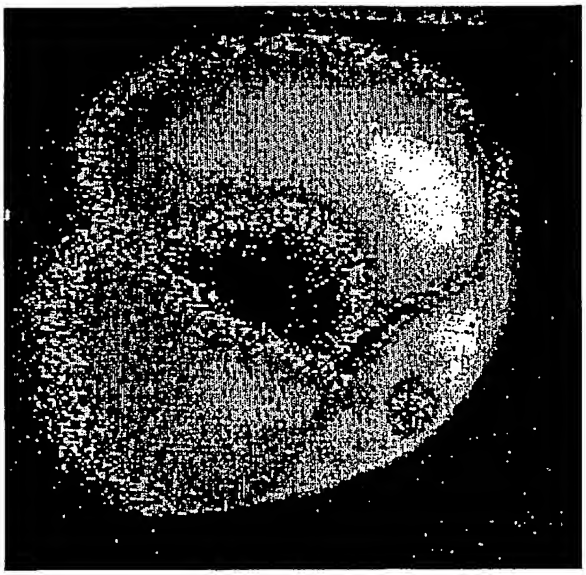


Figure 3

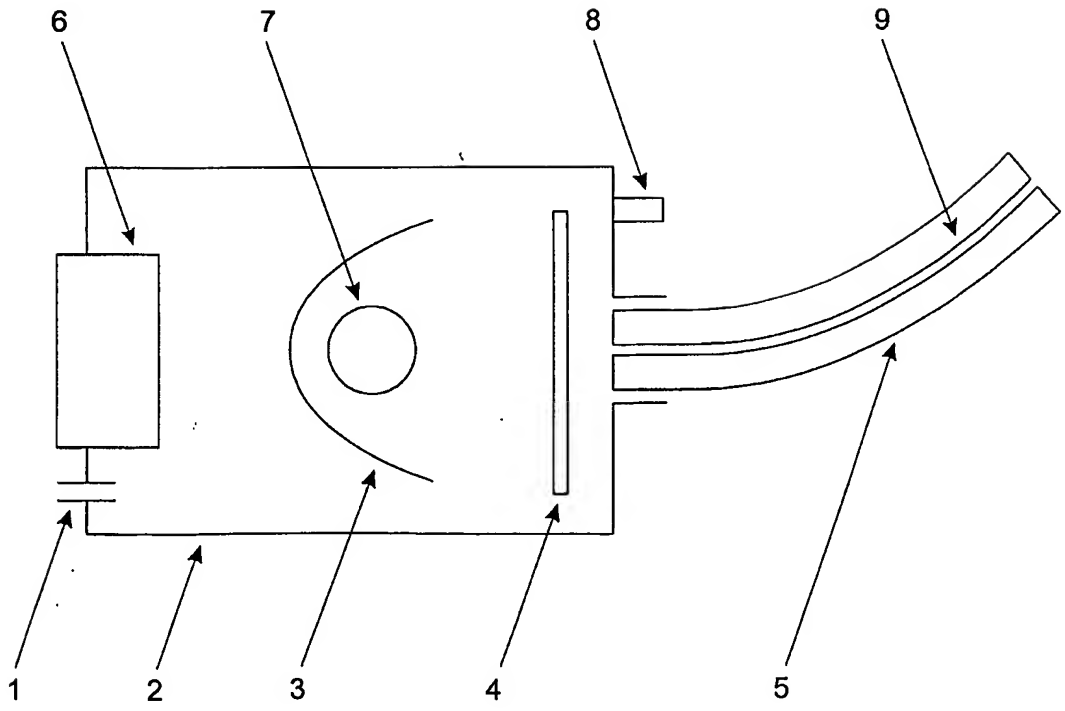


Figure 4

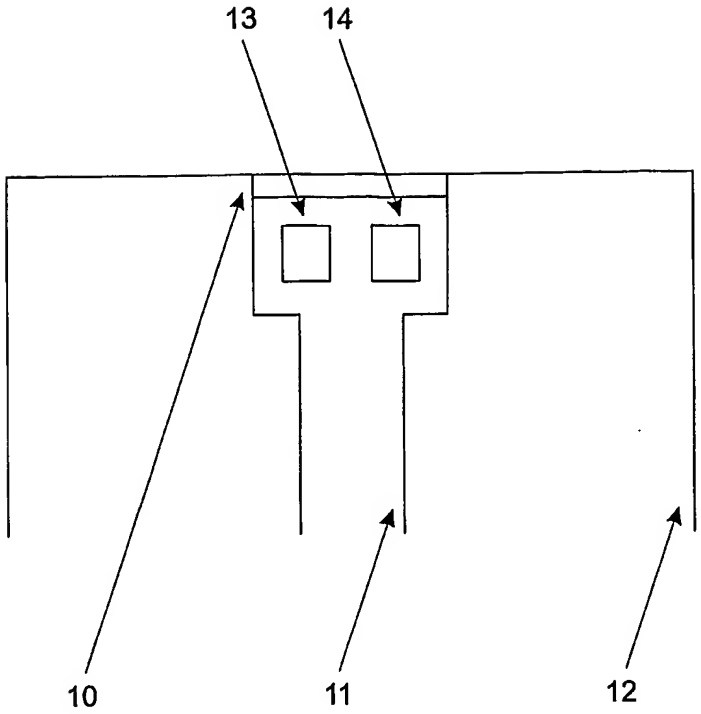


Figure 5

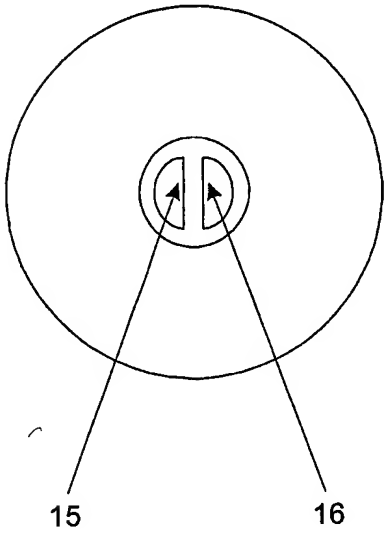


Figure 6

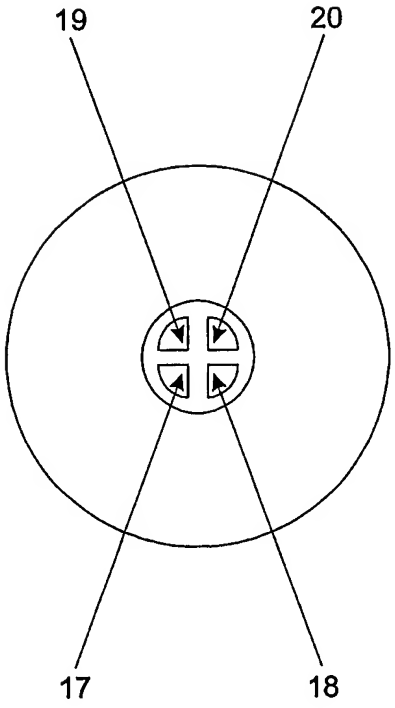


Figure 7.

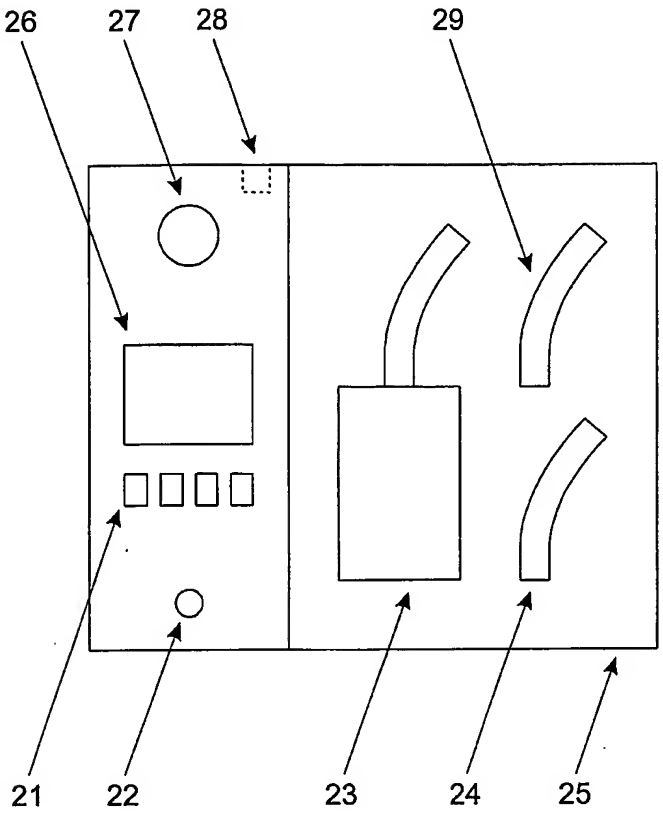


Figure 8

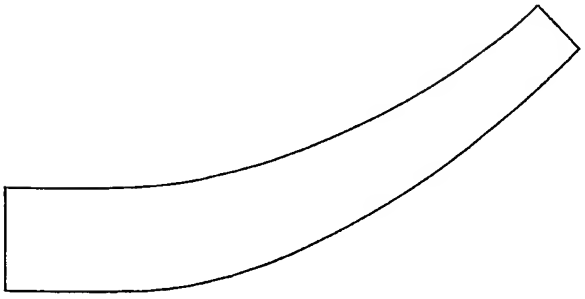


Figure 9.

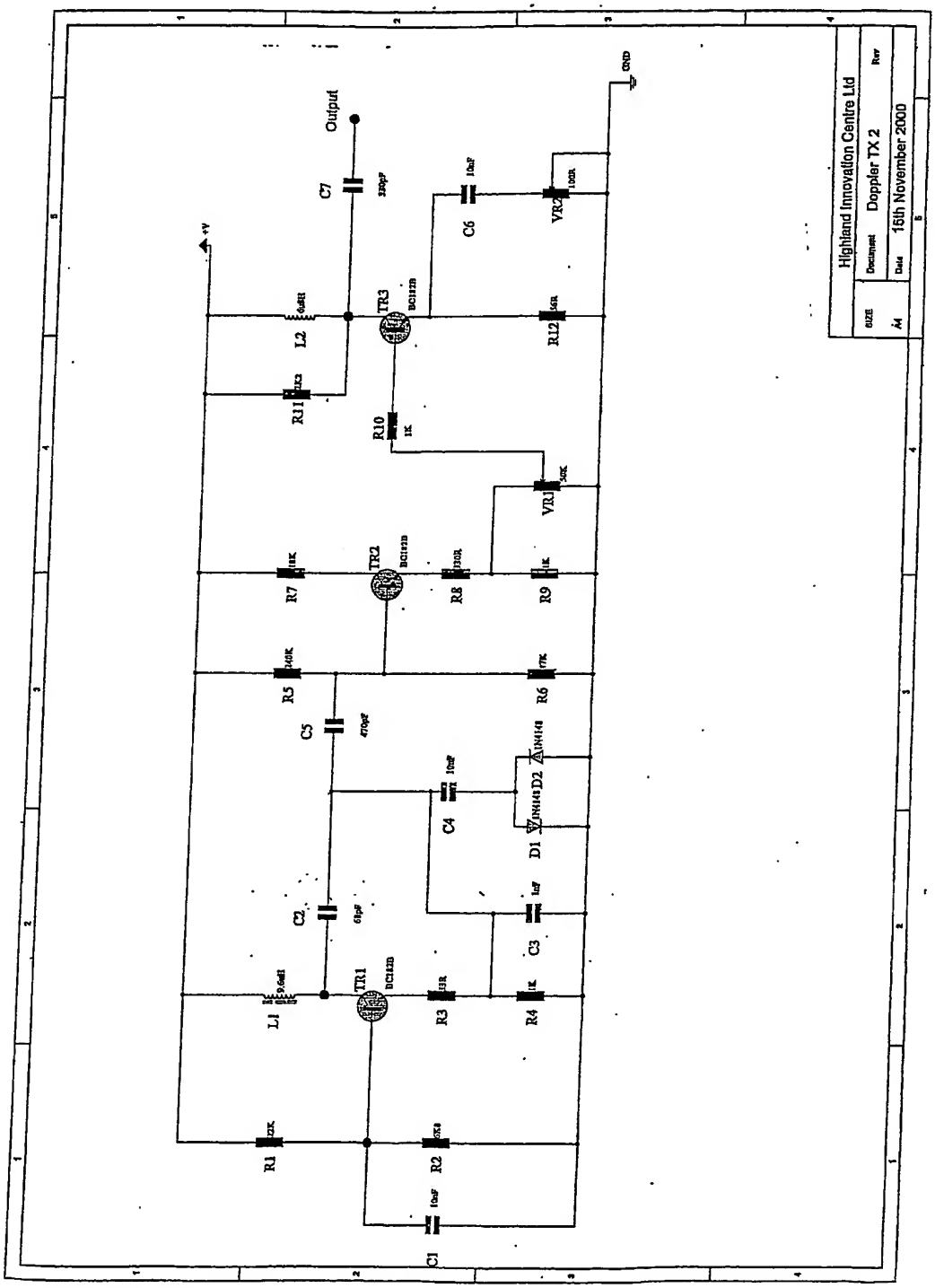

Output
GND
+V
C7
C6
VR2
TR3
L2
R12
R11
R10
VR1
TR2
R7
R8
R9
R5
R6
C5
D2
D1
C4
C2
C3
TR1
L1
R3
R4
R1
R2
C1
Highland Innovation Centre Ltd
Doppler TX 2
16th November 2000

Figure 10a

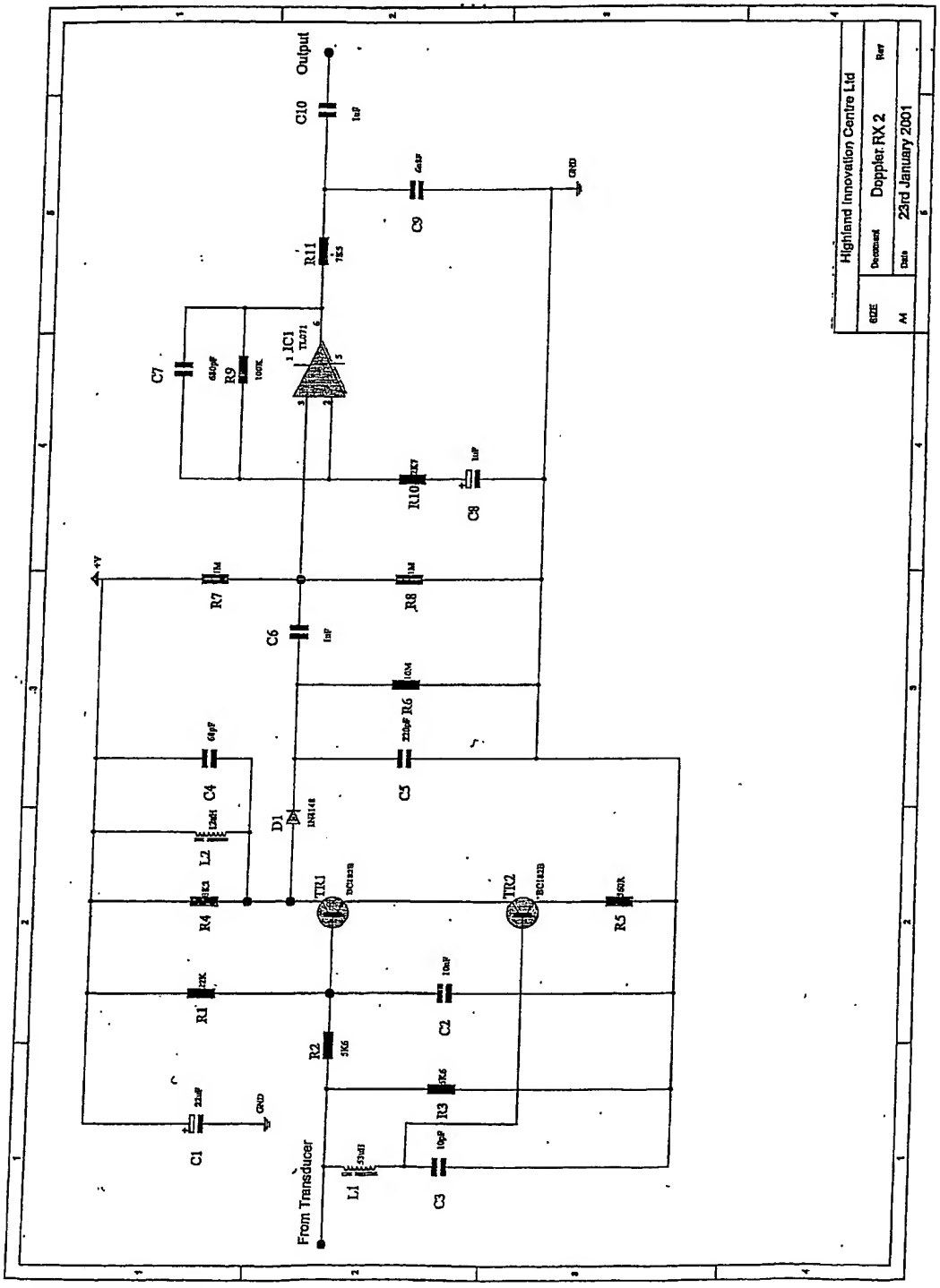

Output
From Transducer
C10
C9
C7
C8
C6
C5
C4
C2
C1
C3
R11
R9
R10
R7
R8
R6
R4
R5
R1
R2
R3
L2
L1
D1
TR1
TR2
IC1
GND
Highland Innovation Centre Ltd
Doppler RX 2
23rd January 2001

FIGURE 10b.

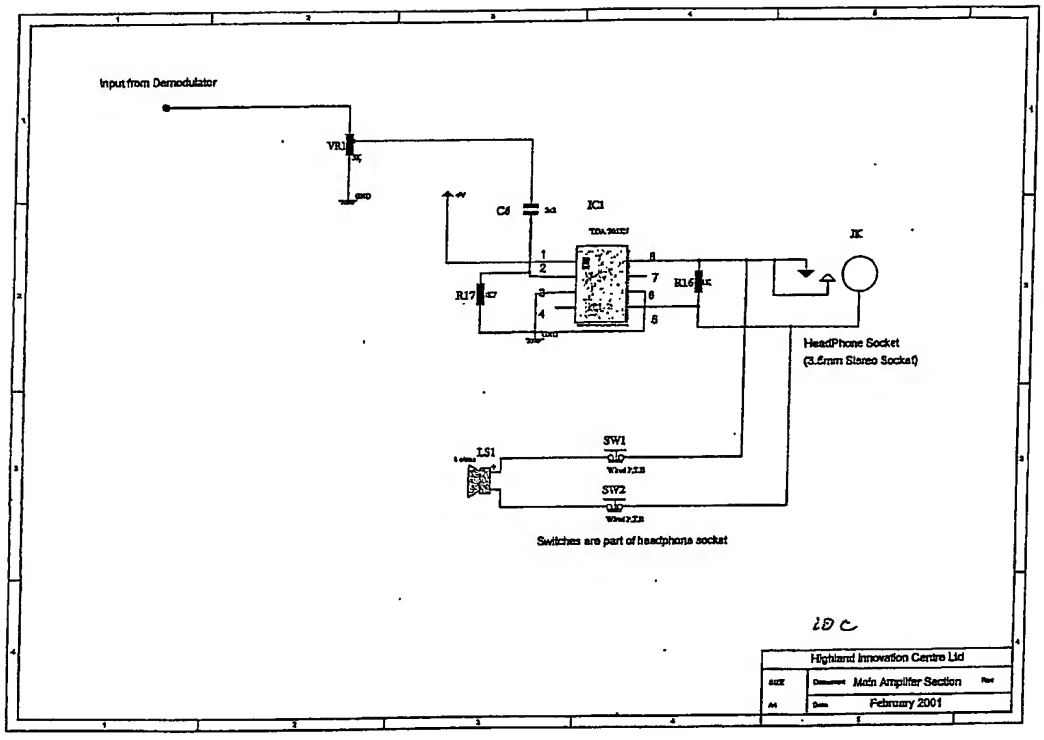
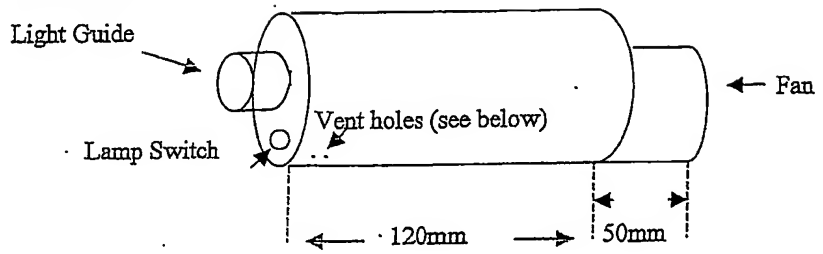

Input from Demodulator
VR1
C6
IC1
JK
R17
R16
HeadPhone Socket
(3.5mm Stereo Socket)
LS1
SW1
SW2
Switches are part of headphone socket
2D C
Highland Innovation Centre Ltd
Main Amplifier Section
February 2001

Figure 10c.

Figure 11.

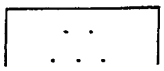
-Torch

Basic shape of torch

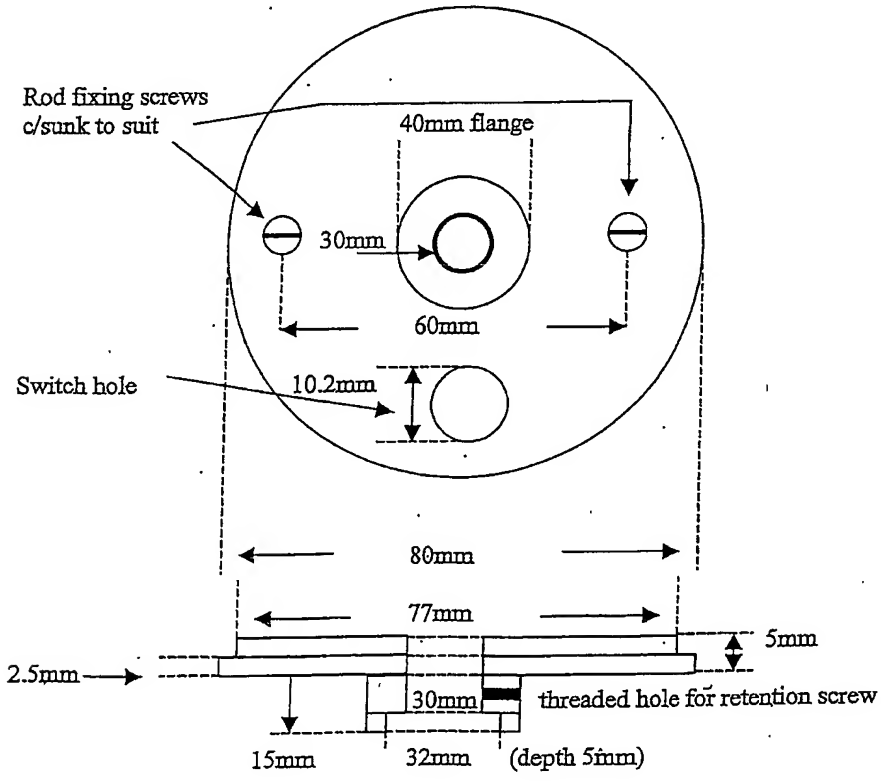


Main tube diameter 80mm Wall thickness 1.5mm drilled at fan end for fixings

Main tube to have 5 * 5mm diameter holes below switch position, 2 @15mm from front edge and 3 @ 28mm from front edge. Holes to be 15mm apart



Front End Plate



DRAWINGS NOT TO SCALE

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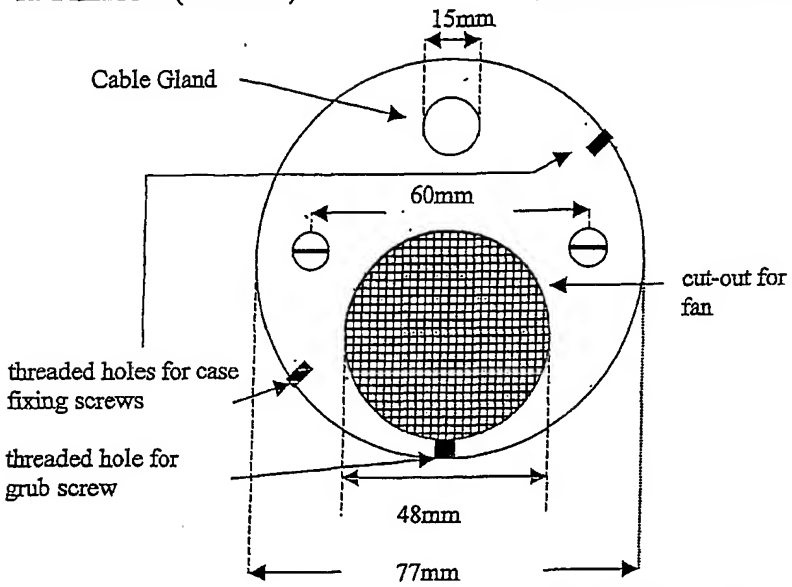
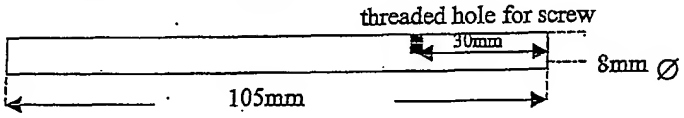
Torch

Rear End Plate (5mm thick) DRAWINGS NOT TO SCALE

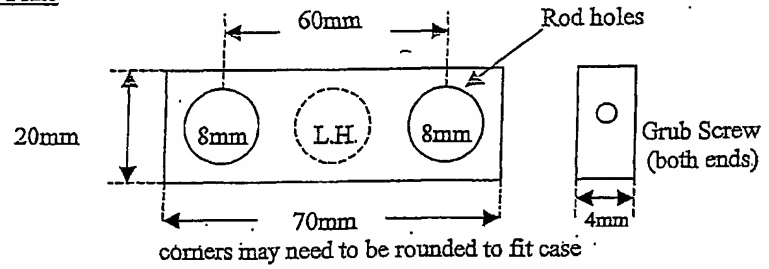


Rods (2 off)



Rods to have internal threads (not shown) at both ends to accept fixing screws from end plates.

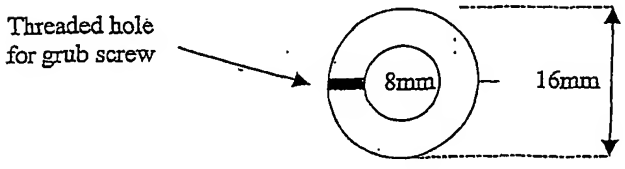
Lamp Plate



corners may need to be rounded to fit case

L.H. space reserved for Lampholder (fixing details to be advised)

Lamp retaining discs (2 off) 4mm thick

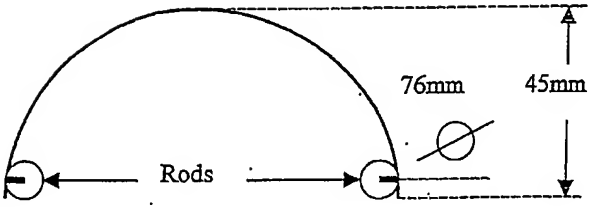


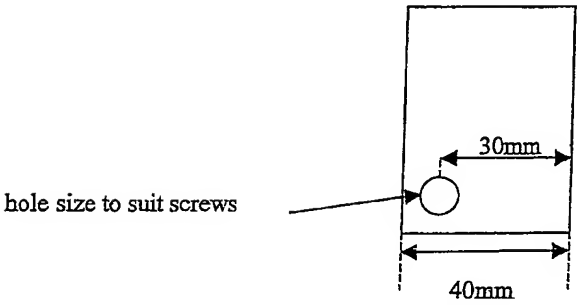
11/11

Torch

Light Restrictor

0.5mm sheet





Light restrictor is to be painted black and fixed to the rods via dome headed screws

DRAWINGS NOT TO SCALE

Note

All dimensions are approximate and are dependent upon the materials chosen, components and tolerances.

INTERNATIONAL SEARCH REPORT

Ir ional Application No
PCT/GB 02/01159

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A61B5/00 A61B8/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 01 58358 A (D.J. WATMOUGH) 16 August 2001 (2001-08-16) cited in the application the whole document	1,2,4,5
Y	US 6 264 610 B1 (ZHU) 24 July 2001 (2001-07-24) column 2, line 49 -column 3, line 60; figures 1-7	1,2,4,5
A	US 4 413 629 A (DURLEY III) 8 November 1983 (1983-11-08) column 4, line 21 -column 5, line 12; figures 1-12	1,5
A	US 4 286 602 A (GUY) 1 September 1981 (1981-09-01) abstract; figure 5	1,6,7

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
27 November 2002	04/12/2002

Name and mailing address of the ISA	Authorized officer
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Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 02/01159

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y	ZHU Q: "IMAGER THAT COMBINES NEAR-INFRARED DIFFUSIVE LIGHT AND ULTRASOUND" OPTICS LETTERS, OPTICAL SOCIETY OF AMERICA, WASHINGTON, US, vol. 24, no. 15, 1 August 1999 (1999-08-01), pages 1050-1052, XP000859237 ISSN: 0146-9592 the whole document	1,4
Y	WO 96 14014 A (TELBUS GESEEESCHAFT FÜR ELEKTRONISCHE KOMMUNIKATIONS-SYSTEME MBH) 17 May 1996 (1996-05-17) page 7, line 24 -page 10, line 24; figures 1-7	1,4

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 02/01159

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